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NECTAR AND POLLEN COLLECTION BY BUMBLE BEES: METHODOLOGY FOR A COLONY-LEVEL APPROACH

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Abstract.—Recent studies of bumble bee foraging (*Bombus* spp.; Hymenoptera: Apidae) stress the importance of examining this behaviour from a colony standpoint. The possible advantages of this approach are demonstrated, employing a methodology which allows repeated measurements of individual pollen and nectar loads brought back to the nest, without disturbing the bees.

In recent years, a large body of literature has emerged on the study of foraging behaviour in bumble bees (see reviews by Morse, 1982, and Pyke, 1985). Despite this extensive data base, very little is known about the collection of pollen, and about the interaction between pollen and nectar collection. Lack of information on these subjects is due to a large extent to the inability to remove pollen and nectar loads without killing or disturbing foraging workers. Another potential drawback is the reliance of most students of bumble bee foraging behaviour solely upon observations of workers in the field. An alternative emphasis, stressing the needs of a given colony and how foraging by workers satisfies those needs, has been forwarded by Heinrich (1983) and Tëras (1985). According to this view, knowledge about how individual decisions are made by workers is not important so long as the success achieved by those decisions (i.e., the amount of pollen and nectar collected) can be measured. In this study, an attempt was made to circumvent these two problems by designing an experimental bumble bee hive which would allow pollen and nectar weights to be calculated without disturbing or sacrificing members of a colony. The hive's usefulness was tested by measuring the collection of pollen and nectar by various-sized workers of *Bombus griseocollis* De Geer.

MATERIALS AND METHODS

One colony of *B. griseocollis* was reared in the laboratory, using the methods of Pomeroy and Plowright (1980). The comb from this colony was moved to another hive, modified in the following way: all existing pollen receptacles (either empty cocoons or wax cylinders constructed by workers especially for the storage of pollen) were removed, and replaced by three false pollen pots. These false pots consisted of plastic tubes (OD 12 mm) placed among groups of cocoons, and extending down through the hive base. Inside each tube a plunger was fitted (a capsule normally used for plastic embedding in electron microscopy) which could be removed from below the hive via a wire handle (see Fig. 1). Previous testing in a flight cage showed that

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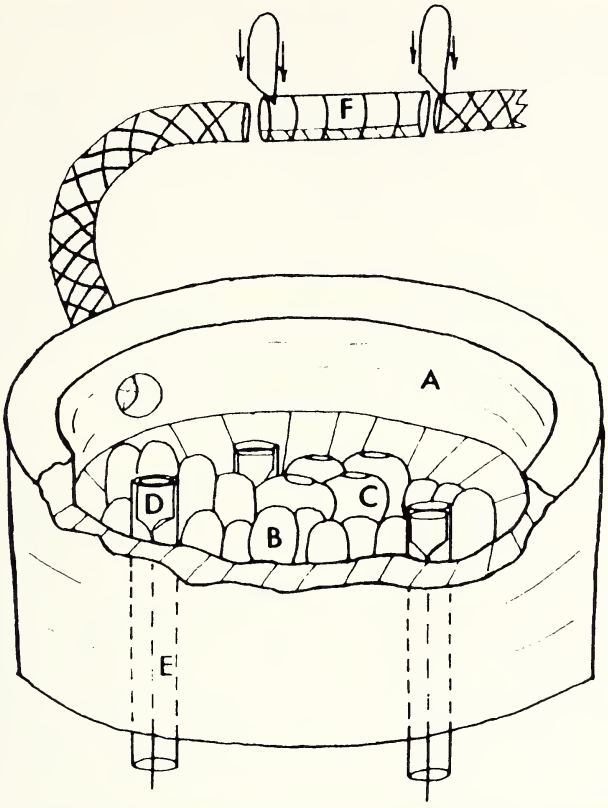

Fig. 1. Experimental hive. Legend: A) hive body, B) brood comb, C) nectar pot, D) plunger of false pollen pot, E) plastic tube, F) weigh cage.

incoming foragers laden with pollen found these false pots suitable substitutes for their normal pollen receptacles (particularly if the pot had previously been primed with a small amount of pollen), and rubbed pollen from their legs into them. The pollen could be removed, weighed, and returned without disturbing the nest. Note: the diameter of the false pots and the use of a hive like that which is illustrated are not critical in pollen measurement, and are provided only as guidelines. There is no reason, for example, why the methodology could not be extended to other groups such as stingless bees (Meliponidae).

The weight of nectar which was brought back to the nest also was measured, by isolating and weighing foragers in a cage as they left the nest, and again when they returned. The weigh cage was constructed from a clear plastic tube (12 mm OD × 50 mm length) with wire mesh floor. The tube was connected at both ends to a flight tunnel. Pieces of plastic card were pushed through slots cut into each end of the cage in order to trap ingoing and outgoing foragers. The entire cage was then removed and weighed. The resulting datum from each returning forager, following subtraction of the outgoing bee weight (and weight of the empty cage), provided the weight of

nectar (+ pollen in some cases). The empty weight of each forager was determined later by food-depriving bees for 12 hr and reweighing them.

The modified hive was connected by a wire mesh tube to the window of a house in Peterborough, Ontario, for a 17 day period beginning 17 July. All of the bees were individually marked. After a five-day adjustment period, 25 *B. griseocollis* workers were monitored while they foraged for nectar. A further 21 workers were monitored while they foraged for pollen. These numbers represent the entire complement of bees which foraged during the experimental period. Observations were conducted at the same time each day, with two periods of observation per day (900 to 1100, and 1300 to 1600 hr EDT). An attempt was made to measure bees of dissimilar weights, and those collecting nectar and pollen, during each observation period (range = 2 to 7 monitored trips per bee). At the end of the experiment, 15 *B. griseocollis* workers were food-deprived for 12 hr and then weighed. The resulting weights, and the length of the wing radial cell for each of the 15 workers were recorded.

RESULTS AND DISCUSSION

A high degree of correlation was found between wing radial cell length and body weight ($r = 0.92$, $P < 0.01$). Thus, further analysis in which bee size was equated with weight was considered justified.

The bees in the colony did not appear to be disturbed either by the temporary removal of pollen, or by their own brief removal from the flight tube in order to weigh outgoing and incoming foragers. In order to compare the foraging behaviour of workers, rates of nectar and pollen collection were calculated by converting the amount with which bees returned to an hourly rate, and averaging this figure for the number of trips made by each bee. Heavier *B. griseocollis* workers were better nectar foragers, irrespective of whether or not they also collected pollen (Fig. 2a: $P < 0.005$ for nectar-only bees, $P < 0.005$ for pollen-collecting bees; Spearman rank correlation for both). A partial explanation for the variance in foraging rate may be the size of nectar load with which workers returned. A comparison between bee weight and the heaviest load with which bees returned (irrespective of trip duration) showed a significant positive relationship ($r_s = 0.55$; $P < 0.01$).

There appeared to be a size difference between nectar- and pollen-collecting bees (see data in Fig. 2a: Mann-Whitney *U*-test; $P = 0.05$). However, there was no relationship between bee weight and the rate of pollen collection (Fig. 2b: $r_s = 0.39$; $P > 0.3$).

The experimental hive which has been described provides an easily manageable way of obtaining repeated measures of nectar and pollen collection from bumble bee workers within a given colony. The results which were obtained with the hive suggest that large *B. griseocollis* workers are better foragers than their smaller nestmates, measured by the weight of nectar with which they return, and by their rate of nectar collection. These findings support the view that the greater cost in rearing larger workers (see data in Pomeroy, 1979) is at least partially repaid by the better rate at which larger bees forage. This is a different result than that of Morse (1978), who found no intraspecific variation in nectar-foraging ability in workers of *B. vagans* Smith, another bumble bee species with variable worker sizes. The study by Morse, however, includes data from bees collecting nectar from a single plant species, and

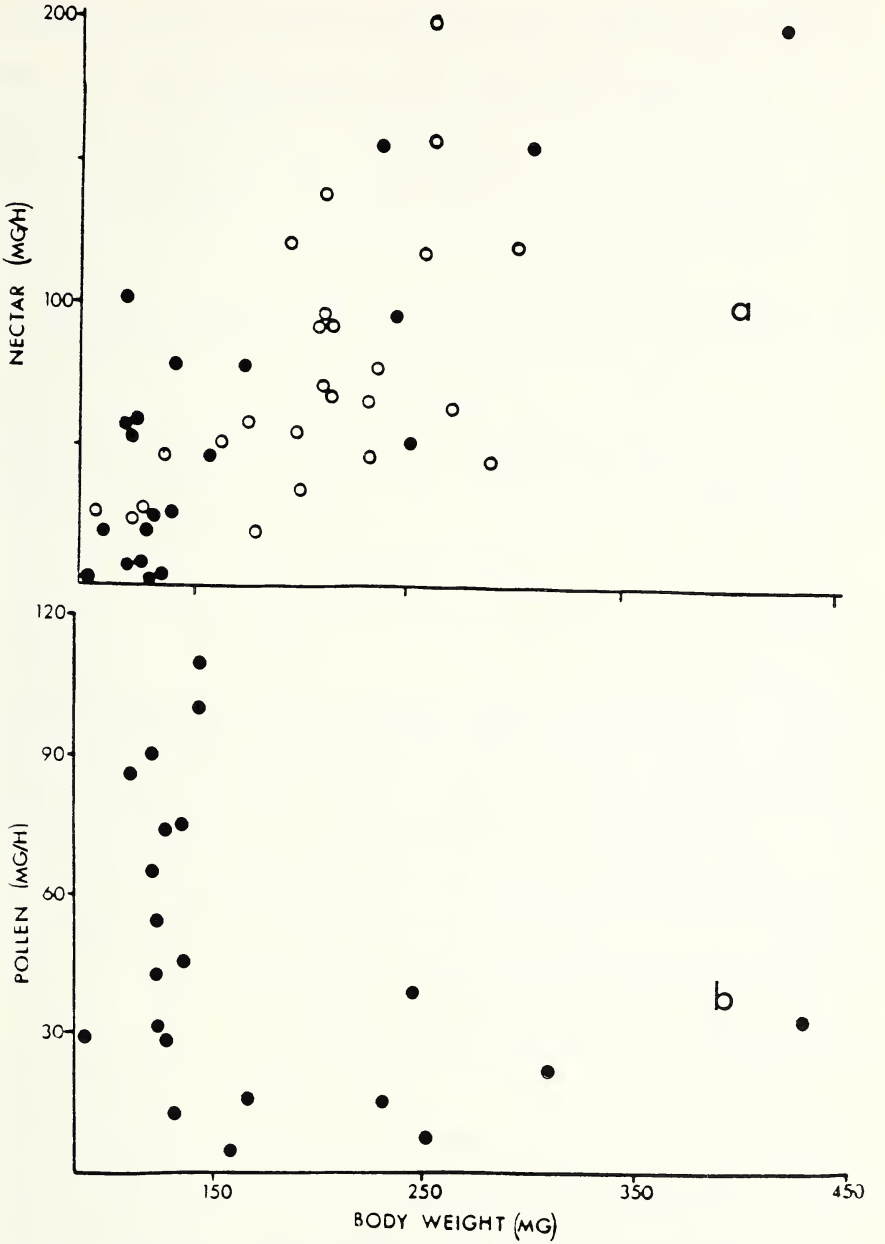

Fig. 2. a) Nectar collection rates of *B. griseocollis* workers of different weights. Clear circles denote bees which collected only nectar, solid circles denote bees which collected both pollen and nectar; b) pollen collection rates of *B. griseocollis* workers of different weights.

may illustrate the differences which can emerge when the present methodology is employed.

That most workers collected nectar while collecting pollen suggests that pollen collection is ancillary to nectar collection. Bumble bee colonies may be better able to withstand pollen rather than nectar shortages (particularly larvae: see Plowright and Jay, 1977), and there may be less selection pressure on colonies to produce workers of different sizes which are differentially proficient in pollen collection. Of course, much more data on a variety of *Bombus* species are required, comprising complete colony developmental stages, before this question can be satisfactorily resolved. Studies such as these can be expanded in scope far beyond this paper, the main purpose of which is to show that much valuable information can be quickly gathered on bumble bee foraging behaviour using the proposed methodology.

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